FreeCable™, an Autonomous Marine Seismic Monitoring System of CO_2 Storage

June 2023

Agenda

- Introduction
- Limitations of the Current Approach
- The Proposed Solution: Kietta FreeCable
- Example of Acquired Dataset
- Conclusion

Introduction

- Monitoring CO2 storages is crucial for predicting the risk of CO2 leakage, increasing efficiciency, reducing the cost of CO2 storage, and reducing the risk of induced seismicity

- Most monitoring surveys are acquired by towed streamers 3D seismic but are challenging in:
  - Image quality
  - Frequency of the repeated surveys
  - Survey size for the CO2 targets

- Kietta developed FreeCable**, an autonomous marine seismic acquisition system** to monitor the offshore reservoirs with a superior quality, increased productivity and competitiveness

- The purpose of this presentation is to show the FreeCable technology and method and demonstrate its advantages and benefits for the CCUS monitoring.

Limitations of the Current Approach

- Image quality of the legacy 3D seismic surveys for offshore CCS is often suboptimal because the towed streamer technique is not well suited to monitor the CO2 plume and potential leakage zones
- The above 4D (or time-lapse) seismic method can not be performed on a frequent basis due to its cost and environmental impact
- Further, it is not adapted to acquire small size surveys which might be sufficient to monitor CO2 targets
- 4D streamer repeatability is challenging and depends strongly on repeating the acquisition parameters such as source and receiver positions
- **Hence, there is a need for a more versatile technology which can focus on custom-fit and on-demand acquisition and can be easily modified and adjusted to the moving CO2 plume by changing the source locations while keeping the receivers quasi-static in midwater.**

Kietta Solution: Overview of the FreeCable System

Array of autonomous Midwater Stationary Cable (MSC)
100% depth control – 100% position control

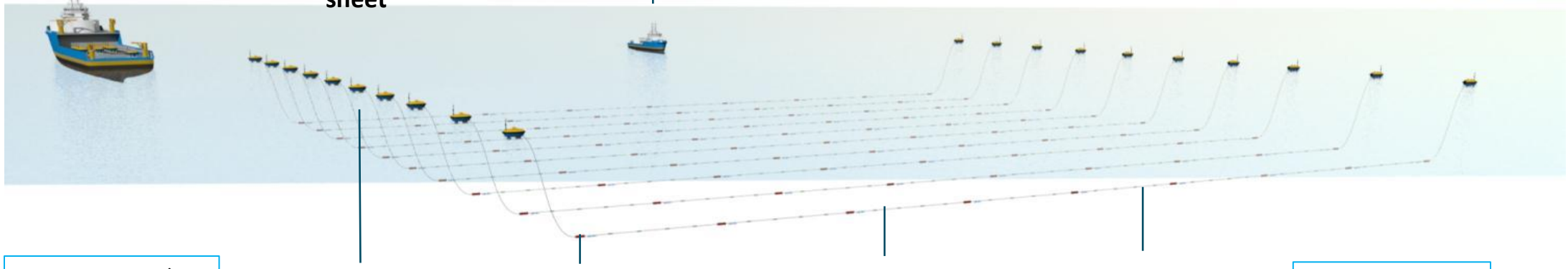
Each cable is automated and independent from others ➔ flexibility in spacing

Master Vessel

10 km

Source vessel(s) criss-cross shooting over the cables

When water depth allows, the seismic cables are immersed below the drifting ice sheet



Down to 100m: it's not moving, no noise, no weather influence, very little tension

RAV
Recording Autonomous Vessel

BALLASTS
every 250m

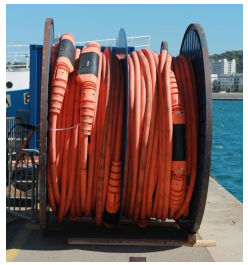
4C SENSORS
every 25m

4C sensors in quiet environment gives excellent Signal/Noise & Broadband data

ACOUSTICS
every 250m

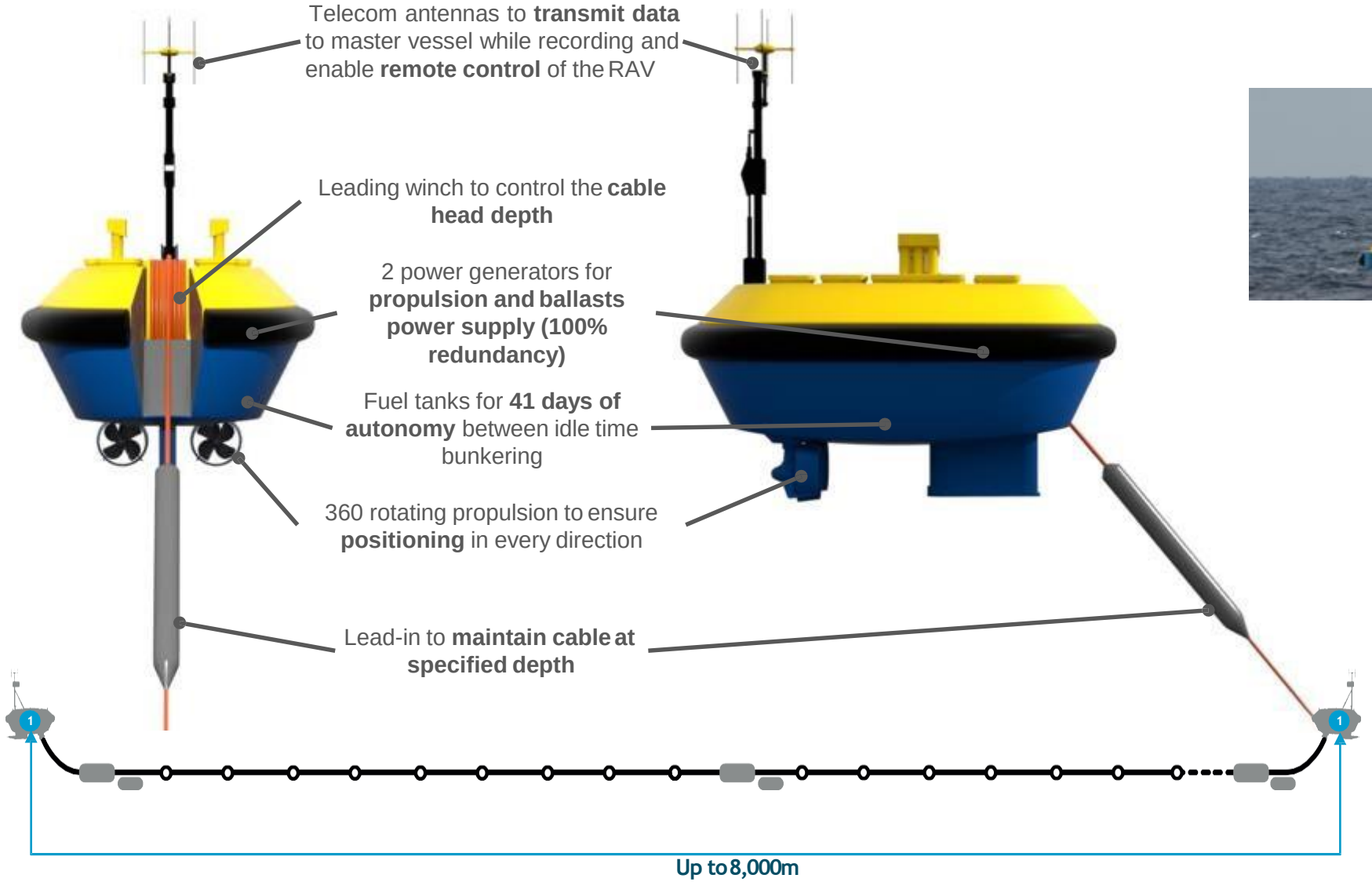
Ideal, homogeneous, coupling for Hydro- & Geo-phones

Specifically Designed Components



Product Description: Specifically Designed Components

Recording Autonomous Vessel (RAV)



Product Description: Specifically Designed Components

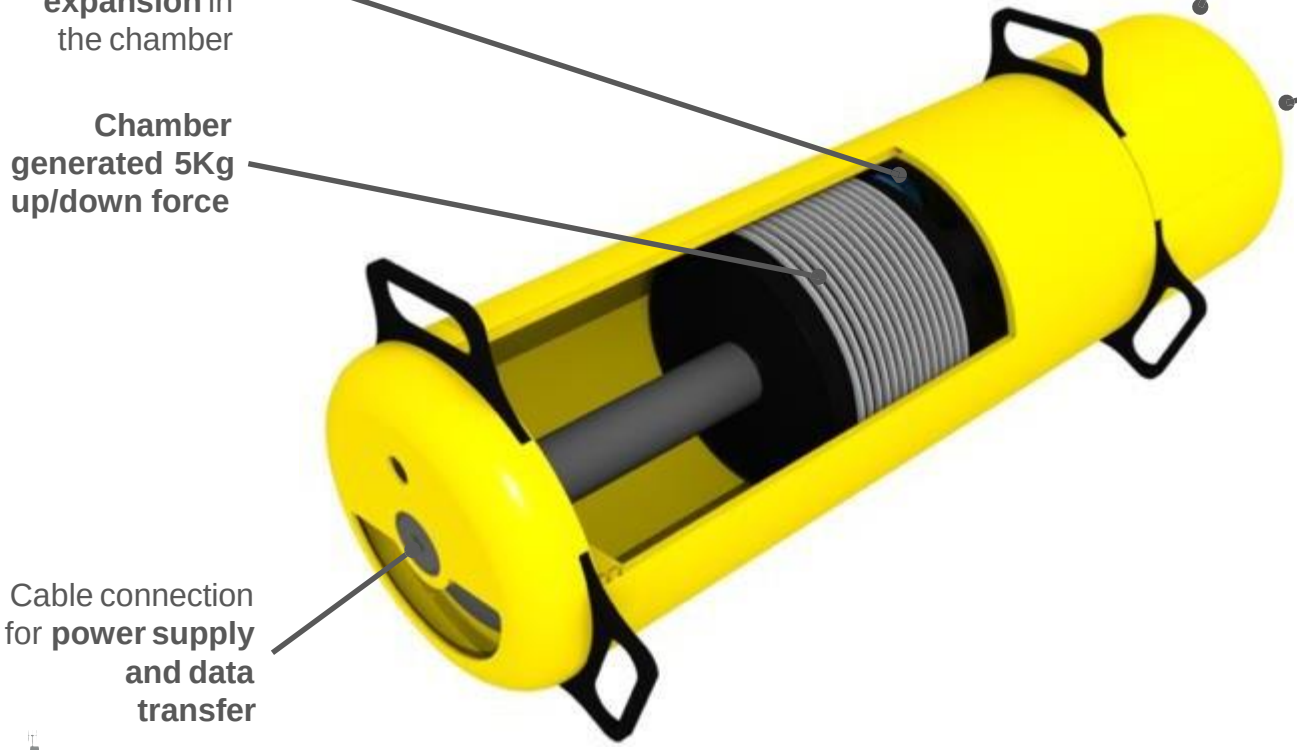
each ballast has its own code and can be **directed independently of others**

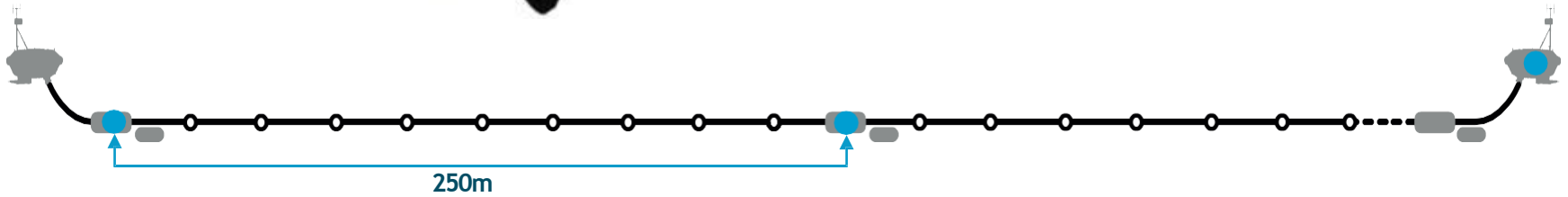
Micro pump creating a **volumetric expansion** in the chamber

Chamber generated 5Kg up/down force

Cable connection for **power supply and data transfer**

Cable connection for **power supply and data transfer**



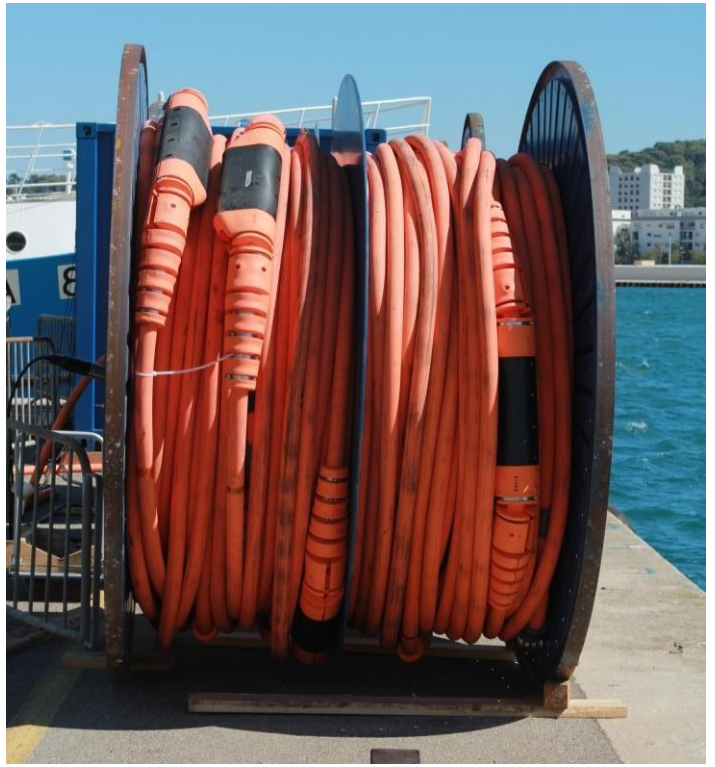


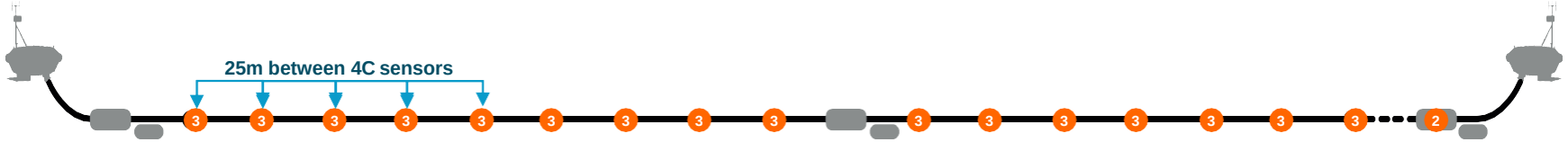
Product Description: Specifically Designed Components

Freecable™ Geospace Cable

Adapted from proven sensor cables

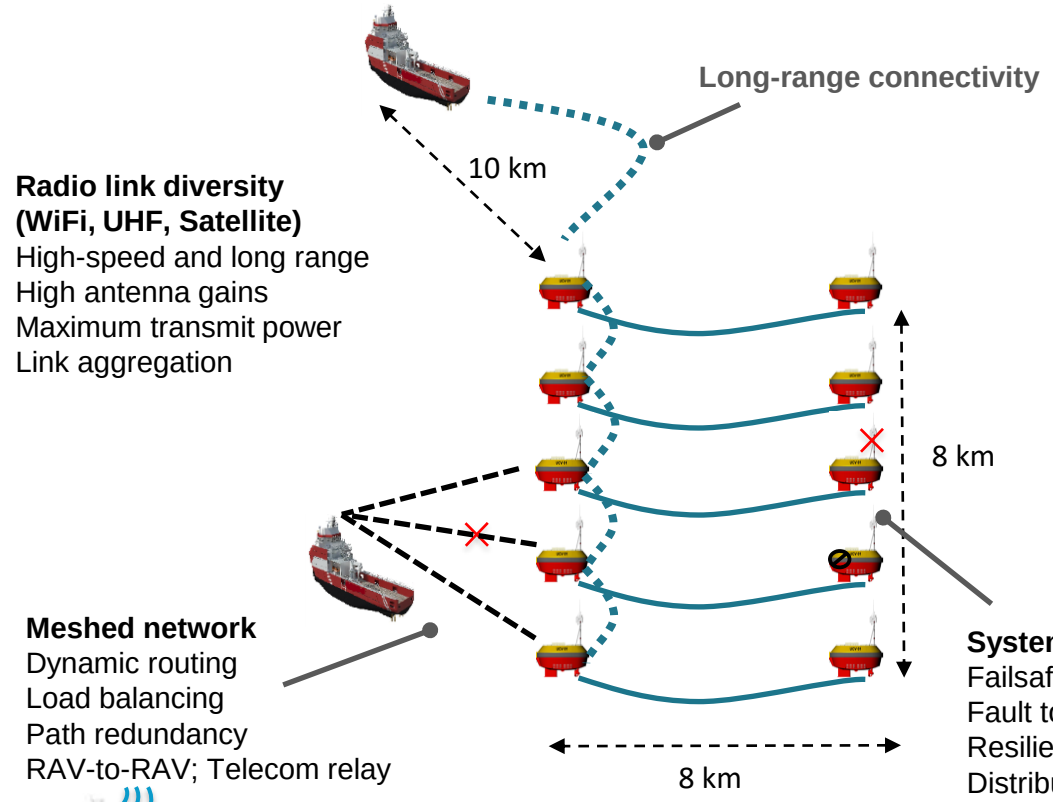
- Neutrally buoyant cable
- Integrated power line for the ballasting system
- Optimization of the housing of the 4 component (4C) sensor modules





Product Description: Specifically Designed Components

Real-Time QC Software Suite

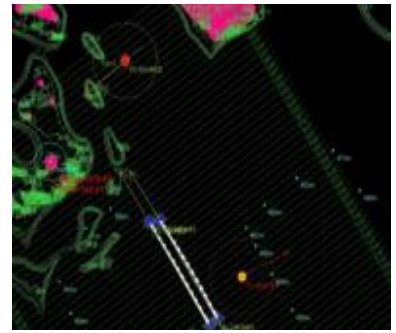


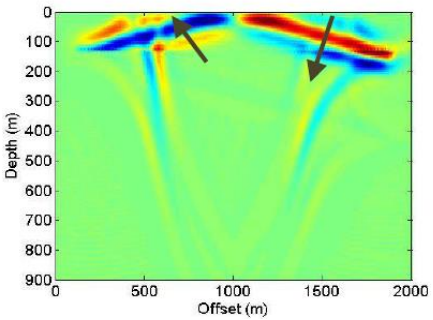
Radio link diversity (WiFi, UHF, Satellite)
High-speed and long range
High antenna gains
Maximum transmit power
Link aggregation

Meshed network
Dynamic routing
Load balancing
Path redundancy
RAV-to-RAV; Telecom relay

System architecture
Failsafe ; Redundancy
Fault tolerance
Resilience
Distributed intelligence

Control Room





Real-time Navigation, Spread Control, and Quality Control

Real-time Quality Control

- **Procedures**
  - **FreeCable provides real-time quality control capabilities and functionalities through data wireless transmission**
  - Real-time seismic acquisition, real-time source QC, real-time navigation QC, end-of-line pre-geometry QC, end-of-line navigation QC, end-of-line post-geometry QC.

- **Integrated navigation system (INS)**
  - GNSS position and speed
  - Attitude data (pitch, roll, yaw)
  - ADCP data (acoustic Doppler current profiler)
  - Cable acoustic ranges
  - Cable and ballast depths.

- **Seismic data processing**
  - 3C geophone rotation according to tilt value
  - Hydrophone/geophone summation (deghosting)
  - Bining according to true trace locations
  - Velocity analysis and 3D stacking
  - Post-stack 3D time migration

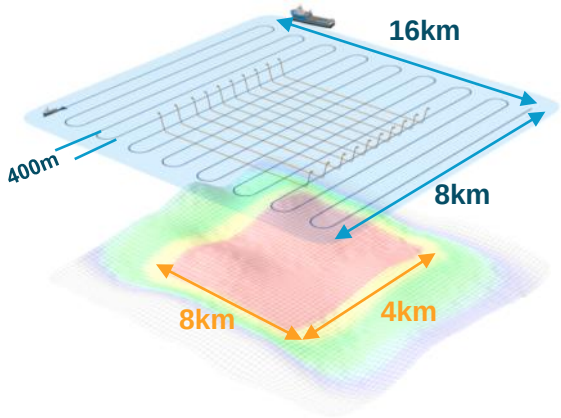
How does the Kietta Technology Work?

Two available acquisition methods combining high productivity and superior data quality – To match any customer requirements

1 Patch Shooting

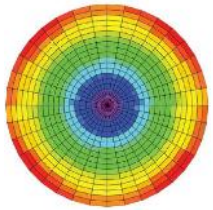
Stationary Autonomous Vessels

- A set of cables is maintained in position in mid water. Each cable is maintained by 2 ARVs, constituting a FCU (Free Cable Unit). Each FCU is independent, making the complete system fully scalable
- A source vessel shoots seismic waves orthogonally to the direction of the cables, generating high density, full azimuth, and long offset data



Data Quality

Full Azimuth Coverage



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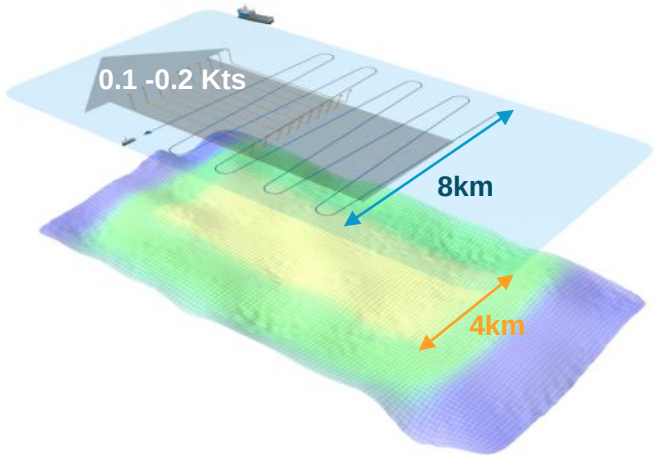
2 Progressive Shooting

Moving Autonomous Vessels

- Same disposition as for Patch Shooting mode, but all the cables (FCUs) are moving at a slow pace (less than 1 knots) to increase productivity
- Similar richness of data as in Patch shooting but with a lower density – still significantly higher than what can be acquired with any type of towed streamers



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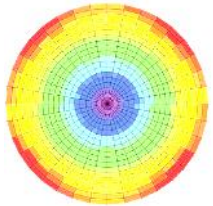
Full Azimuth Coverage



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FreeCable Advantages & Benefits

- **Superior seismic data quality and 4D signal**
  - The system being quasi-static and immersed, it enables to deliver high signal-to-noise, full-azimuth, full-offset, high-fold and broadband data
  - Increased 4D repeatability

- **High productivity and competitiveness**
  - The proposed solution will be **twice** faster and **50%** cheaper than existing methods

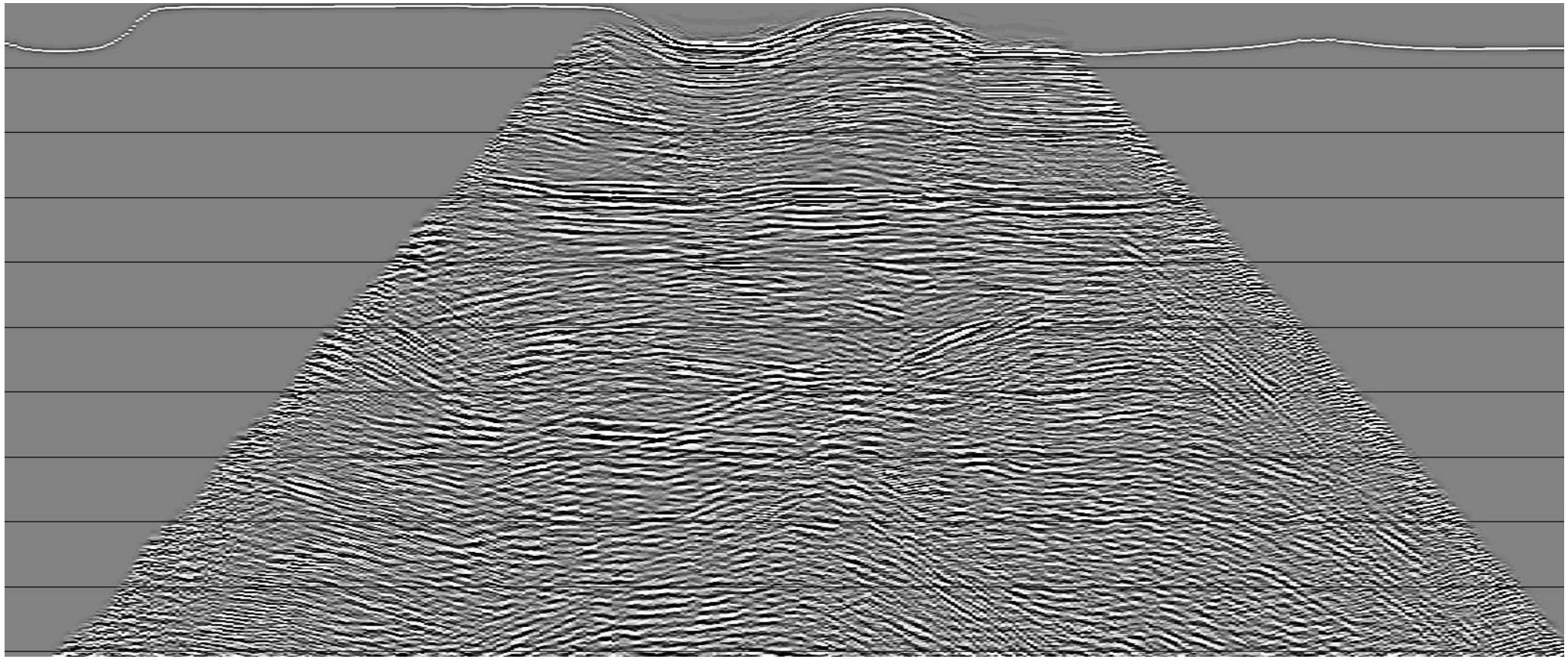
- **Easy deployment and flexibility; custom-fitted for CO_2 storage monitoring**
  - RAVs have been designed to be easily shipped & mobilized worldwide
  - Scalable system and monitor duration/frequency to target CO_2 zones of interest

- **HSE**
  - **Reduced crew mobilized for offshore operations**
    - The master boat crew can manage the 2 ASVs: the number of people / days of operations is reduced
  - **Regulation compliant**
    - ASV authorization to sail is simple to get when ASVs are accompanied by a master boat
  - **Low-carbon footprint and marine life-friendly**
    - Reduced CO_2 with respect to seismic vessels. Zero impact on seafloor and marine life, the sensors being in midwater.

FreeCable Seismic Data

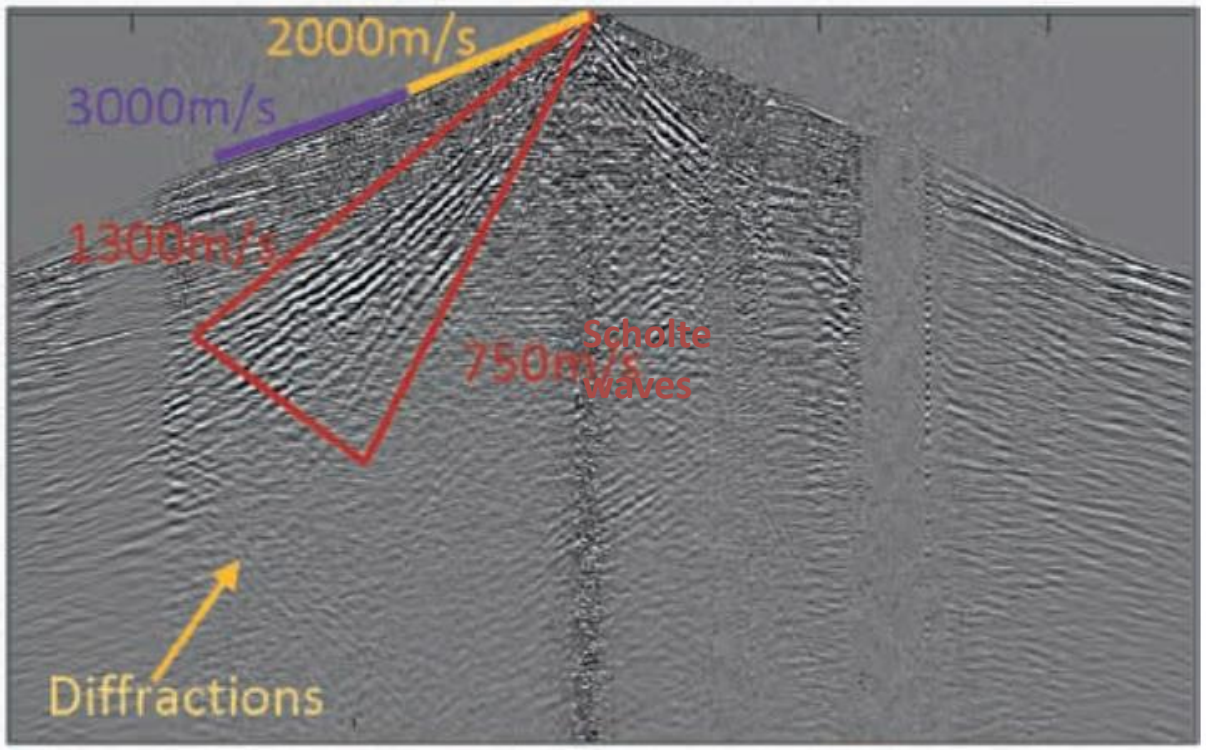
3D processed stack - block S79

- Surface-consistent images
- Preserved amplitude
- Homogeneous seismic resolution
- Frequency content down to 2Hz

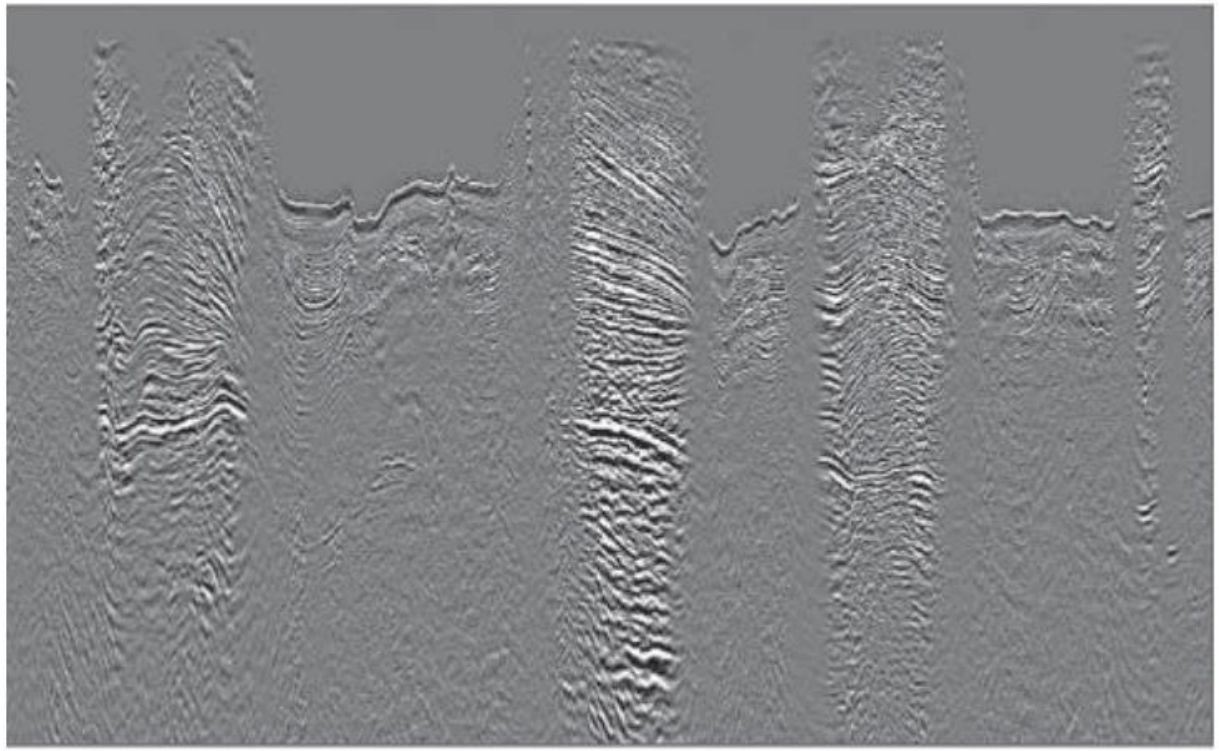


OBS Data in the Same Area of the Red Sea (For Comparison)

Raw data masked by surface waves



Vertical stripes due to heterogeneous sensor coupling responses



Source: First Break, volume 35, November 2017

Conclusion

- According to directives and standards for carbon storage, 4D seismic is the conventional monitoring technology available which, however, has a high impact on cost and environment

- **FreeCable is an alternative approach to conventional 4D seismic because it enables to deliver a custom-fit and on-demand subsurface image and characterization thanks to the system flexibility** (e.g. use few short midwater stationary cables to monitor CO2 plume or potential CO2 leakage zones)

- Furthermore, **FreeCable flexibility allows** to accommodate for future obstructions like windfarms, platforms, or pipelines, **ensuring operability for decades of monitoring**

- FreeCable would have positive impact on the commercial viability and environment of CCS projects.